# Application of the CERES Flux-by-Cloud Type Simulator to GCM Output

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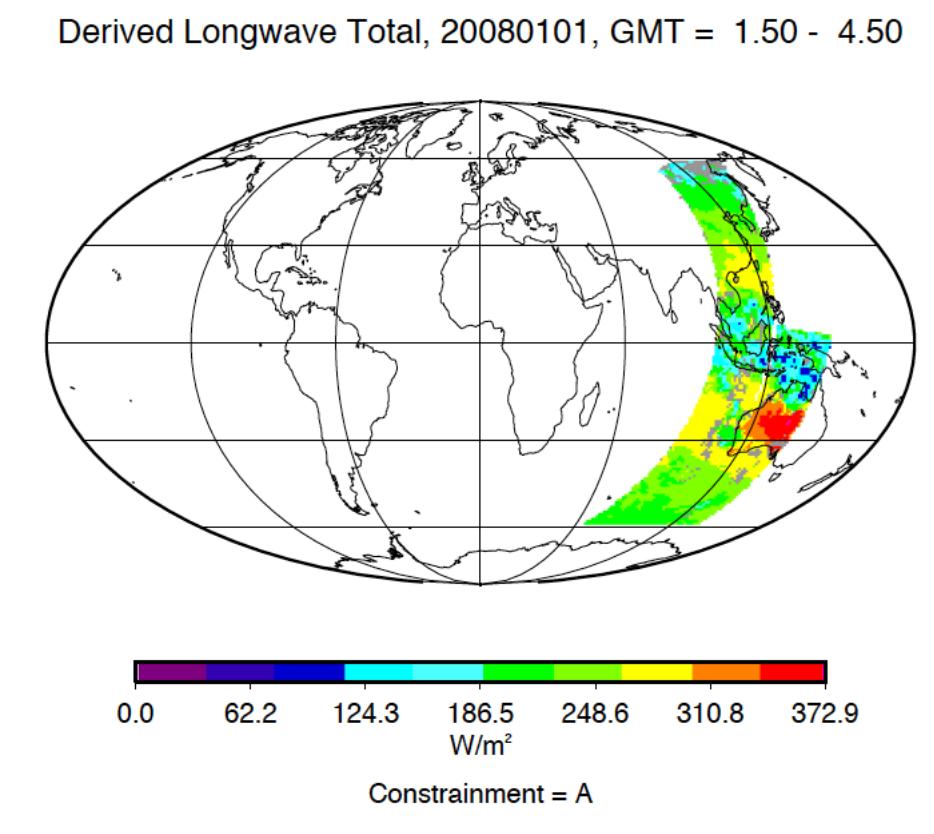
# What is the Flux-by-cloud type product?

- Assigns a flux to each observed ISCCP cloud type within a region.
- For each 1°x1° region between 60° S and 60° N, each daytime footprint is placed into 1-3 $p_c$-$\tau$ ISCCP-like categories (3 categories would be the case of a footprint with two cloud levels as well as clear pixels).
- For the footprints with a single cloud type, the standard SSF flux is added to that $p_c$-$\tau$ category.
- For footprints with multiple cloud levels, narrowband-to-broadband radiance conversions are performed for each cloud level.
- Broadband radiances are converted to fluxes using ADMs.

# What is a simulator?

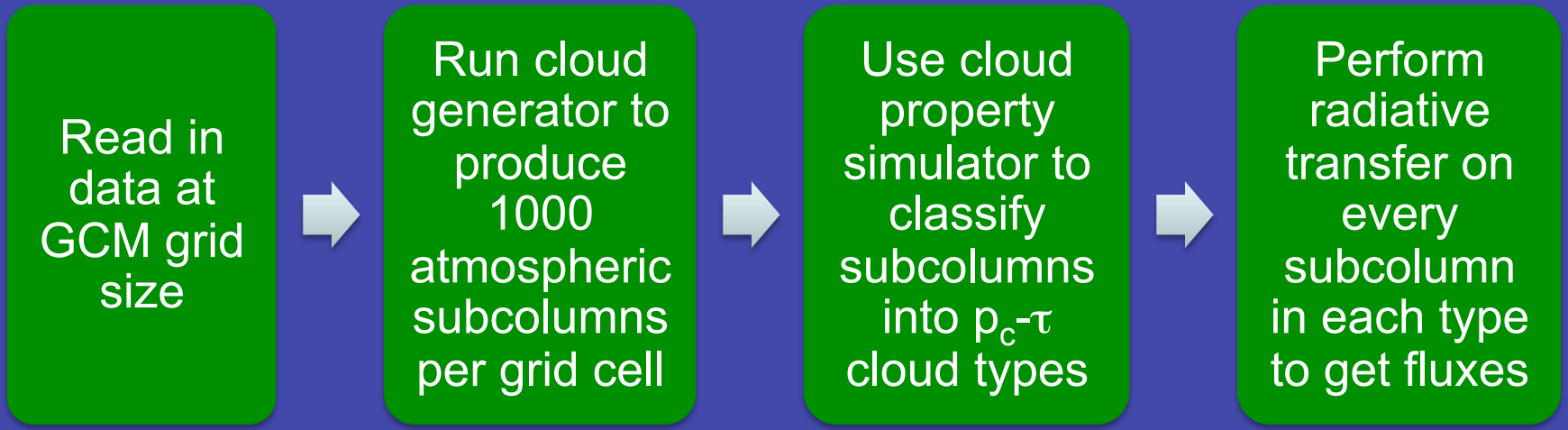
- Put simply, a simulator is meant to replicate what a space-based instrument would measure if it flew above a GCM or other model on the temporal and spatial scales of the measurements.



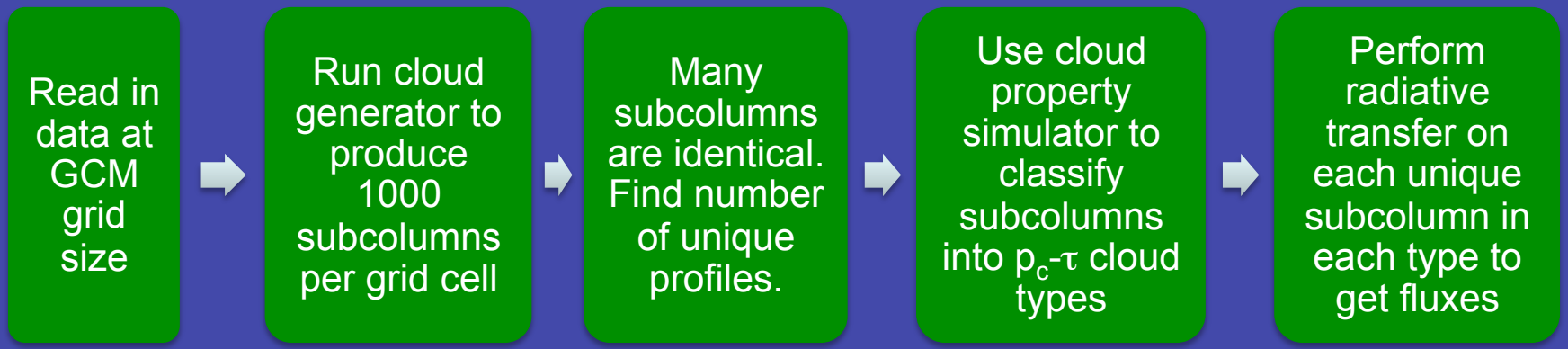
# Motivation for flux-by-cloud type simulator

- Cloud properties and fluxes/albedos will be matched within 1.5 hours to the closest CERES overpass, which is important because of the large diurnal cycles in cloud fraction, $\tau$, and $p_c$ in many areas.
- Breaking out the flux by cloud type can help isolate physical parameterizations that are problematic (e.g., convective clouds, boundary-layer parameterizations, or processes involving surface albedo), and provide a test for new parameterizations.
- Diagnoses using flux-by-cloud type combined with frequency of occurrence can also help determine whether an unrealistically small or large occurrence of a given cloud type has an important radiative impact for a given region.

# Outline of Simulator Approach

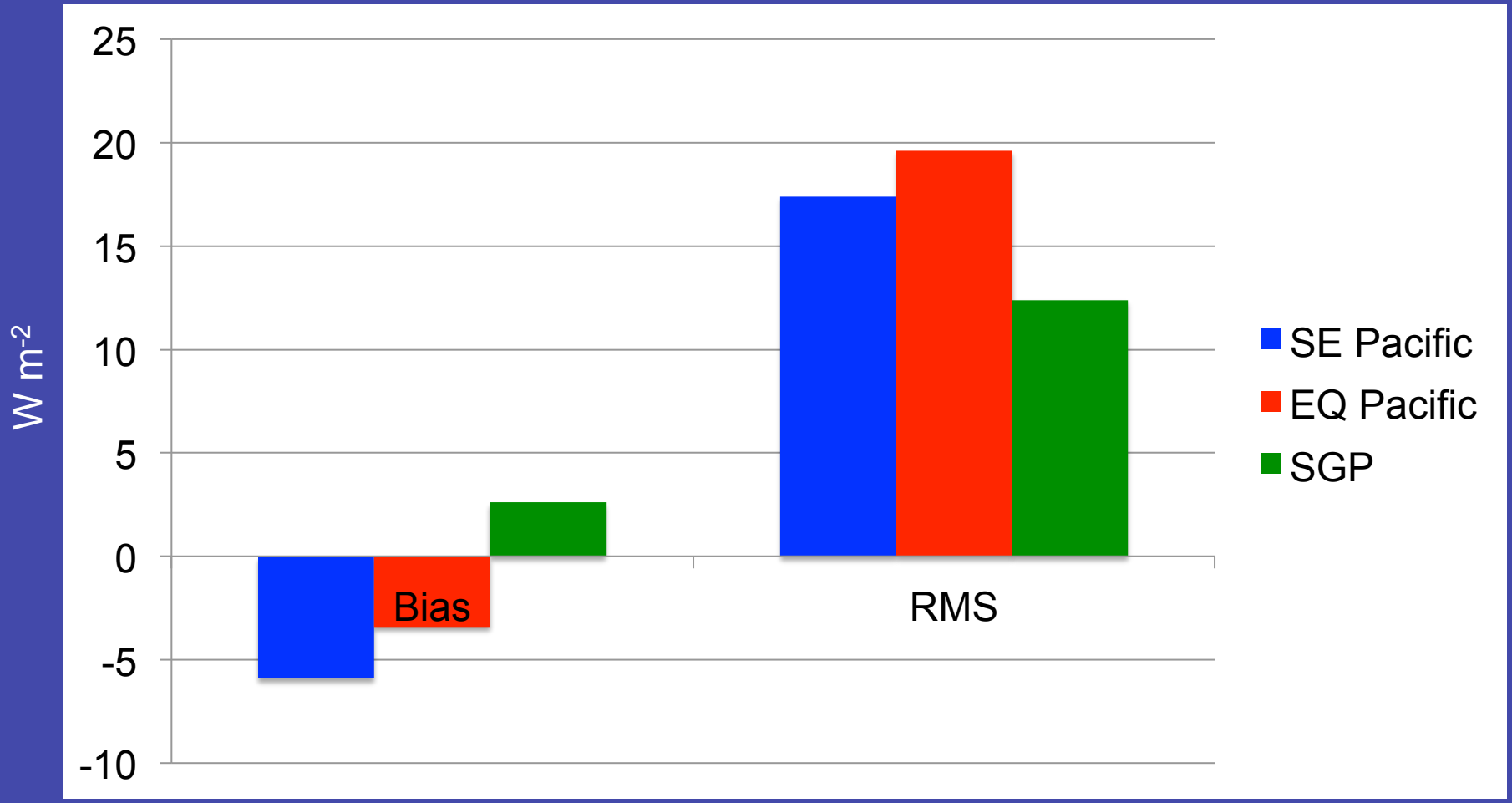


# Outline of *Faster* Simulator Approach

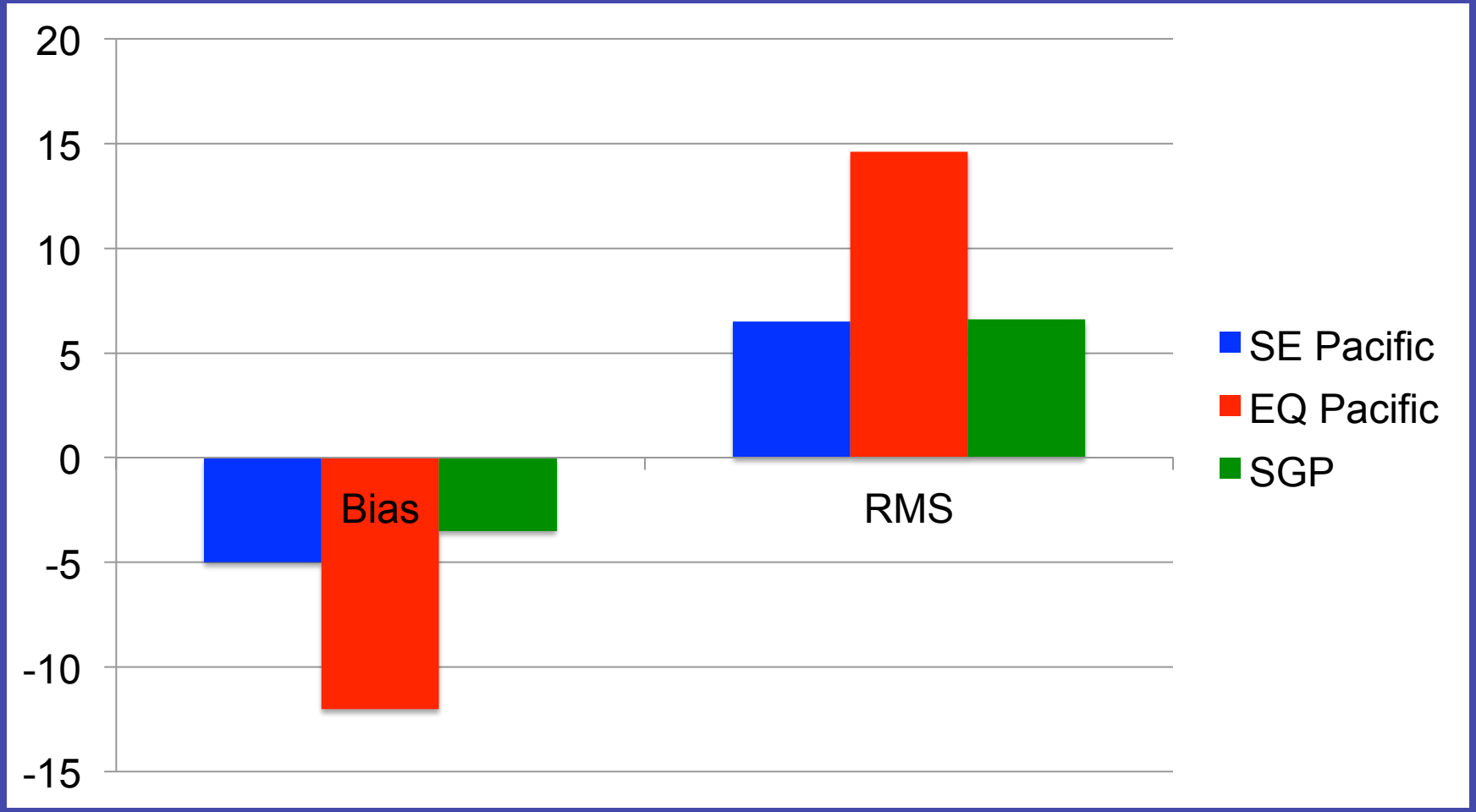



Number of RT calculations needed now depends on how much variety of clouds there is in a given grid box, but for the three regions here, the number of calculations is reduced by 95-99%.

# SW Flux consistency check (Simulator- HadGEM2-A): Subcolumns reproduce GCM grid-scale SW fluxes fairly well



# LW Flux consistency check: Simulator has negative biases, especially over Eq Pacific. RMS errors are mainly due to biases.



# Southeast Pacific results

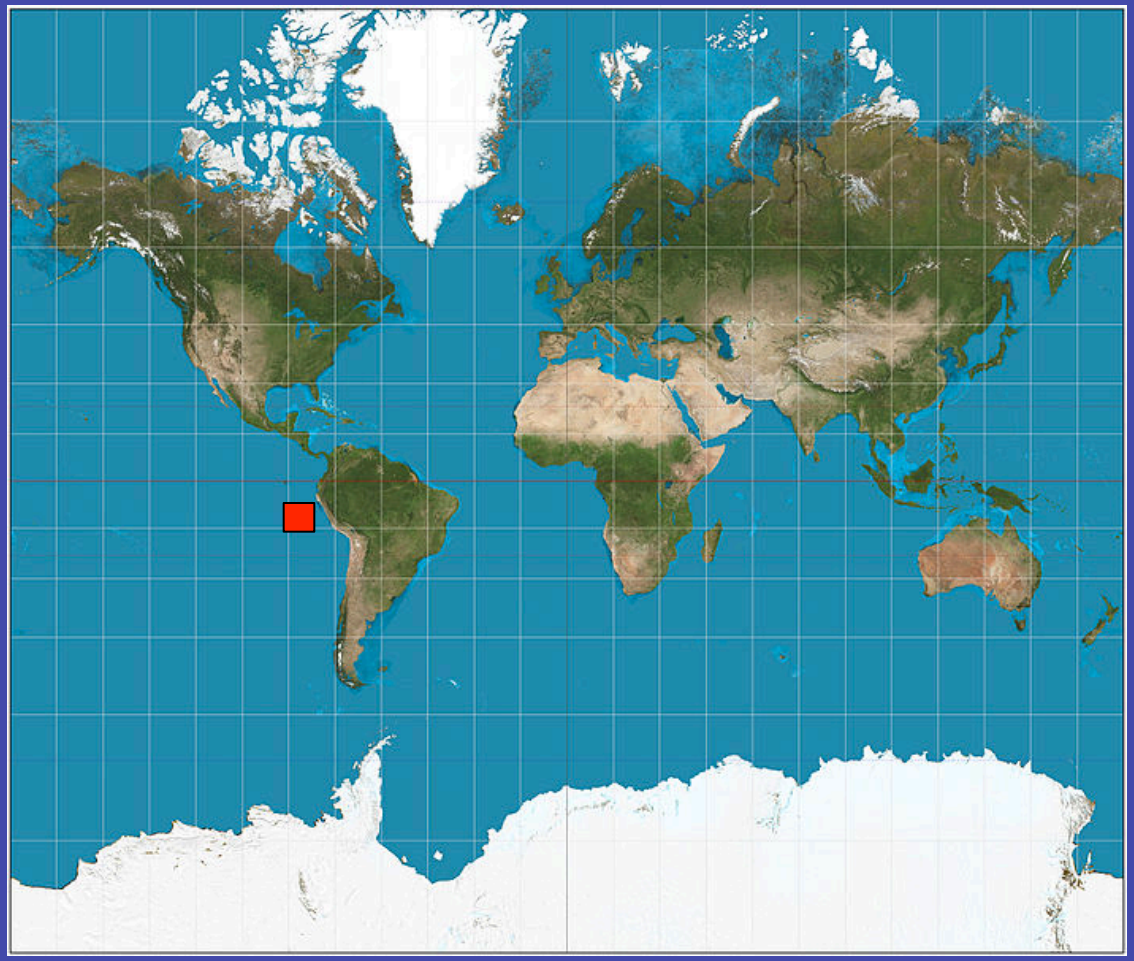
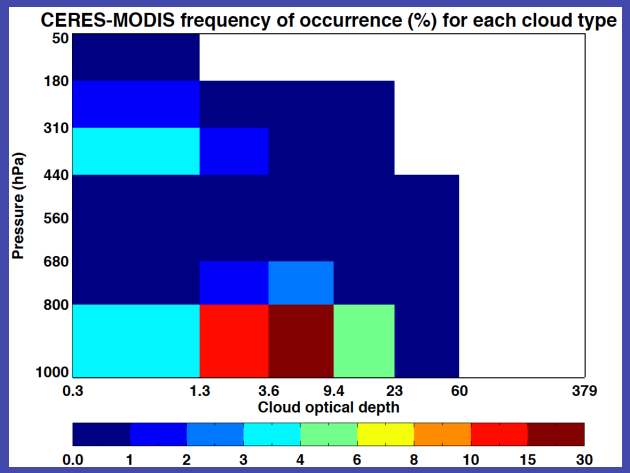


Image from Strebe, https://commons.wikimedia.org/wiki/File:Mercator_projection_SW.jpg

# Cloud fraction (%) for CERES, HadGEM2-A over SE Pacific (Jan 2008)

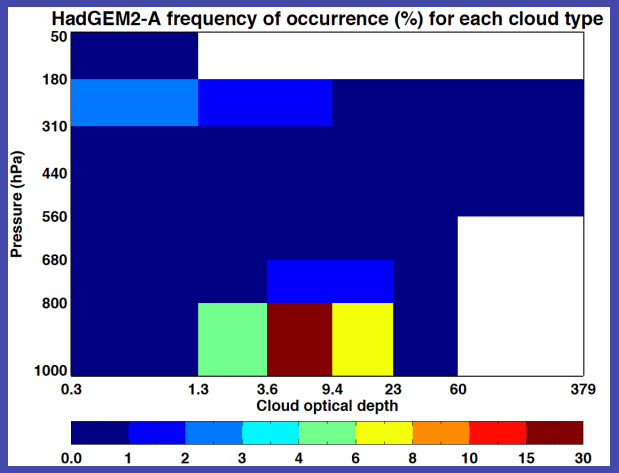
CERES




$p_c$

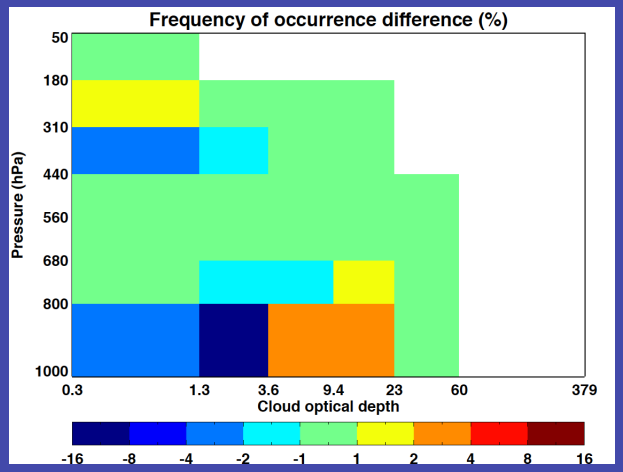
$\tau$

HadGEM2-A




$p_c$

$\tau$




$p_c$

$\tau$

HadGEM2-A – CERES. Good general pattern, but too many low, thick clouds and not enough low, thin clouds.

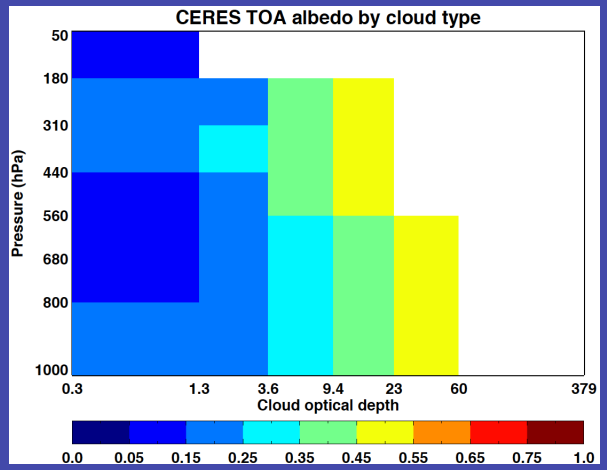
Grid-mean total cloud fraction:
CERES: 0.578
HadGEM2-A: 0.475

# TOA SW albedo by cloud type for CERES, HadGEM2-A over SE Pacific (Jan 2008)

CERES

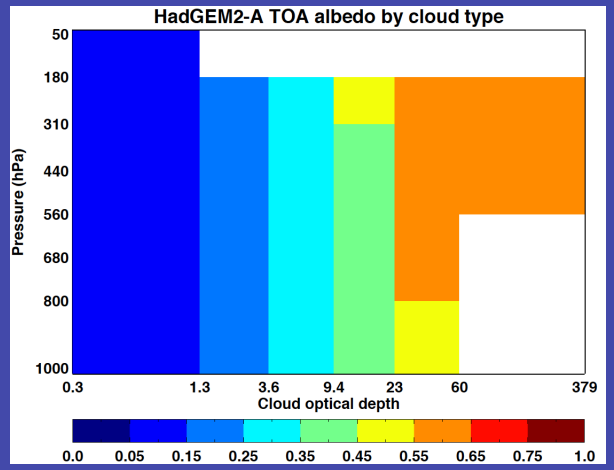
HadGEM2-A

$p_c$



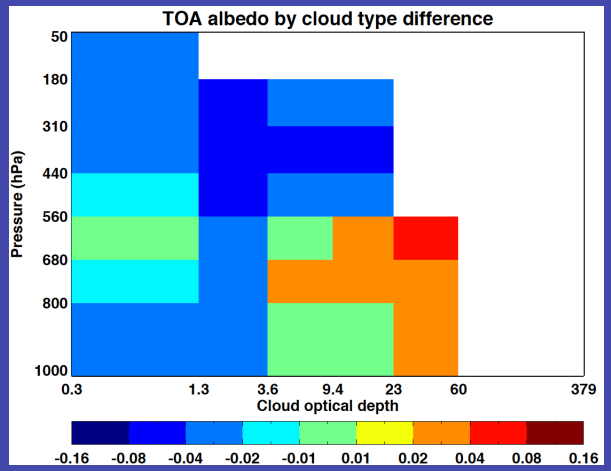

$\tau$

$p_c$




$\tau$

$p_c$



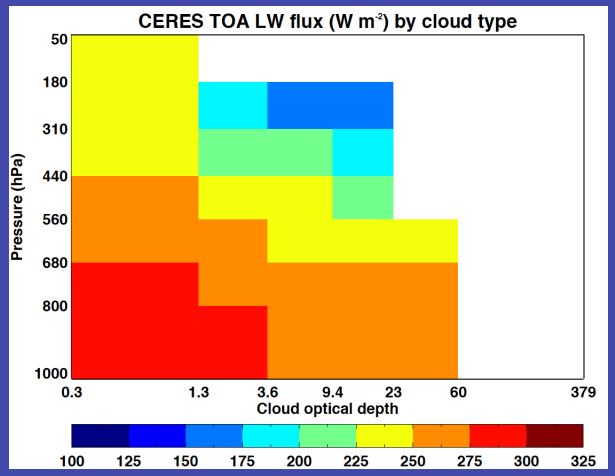

$\tau$

HadGEM2-A – CERES. Albedos a bit low for most cloud types, but high for the highest optical depths

Grid-mean all-sky SW albedo:
CERES: 0.193
HadGEM2-A: 0.189

# TOA LW flux by cloud type (W $m^{-2}$) for CERES, HadGEM2-A over SE Pacific (Jan 2008)

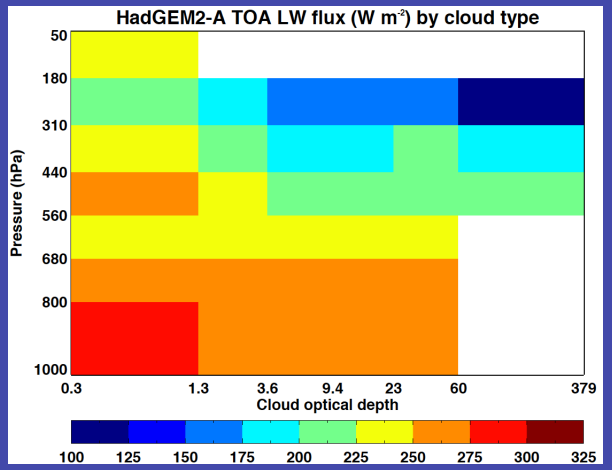
CERES




$p_c$

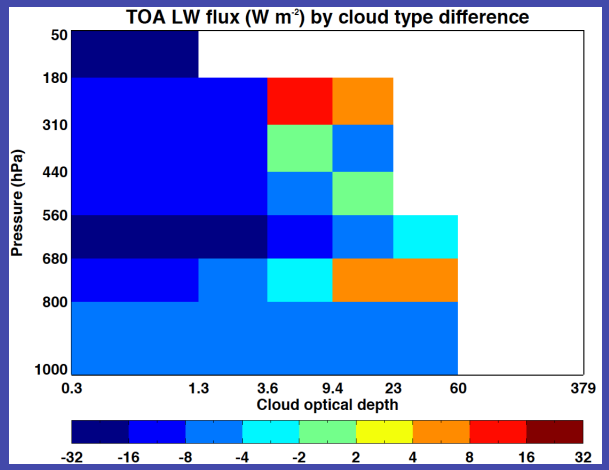
$\tau$

HadGEM2-A




$p_c$

$\tau$




$p_c$

$\tau$

HadGEM2-A – CERES. OLRs are low for most cloud types, but too high for some high- and medium-top clouds.

Grid-mean all-sky OLR:
CERES: 272.4 W $m^{-2}$
HadGEM2-A: 275.5 W $m^{-2}$

# Equatorial Pacific results

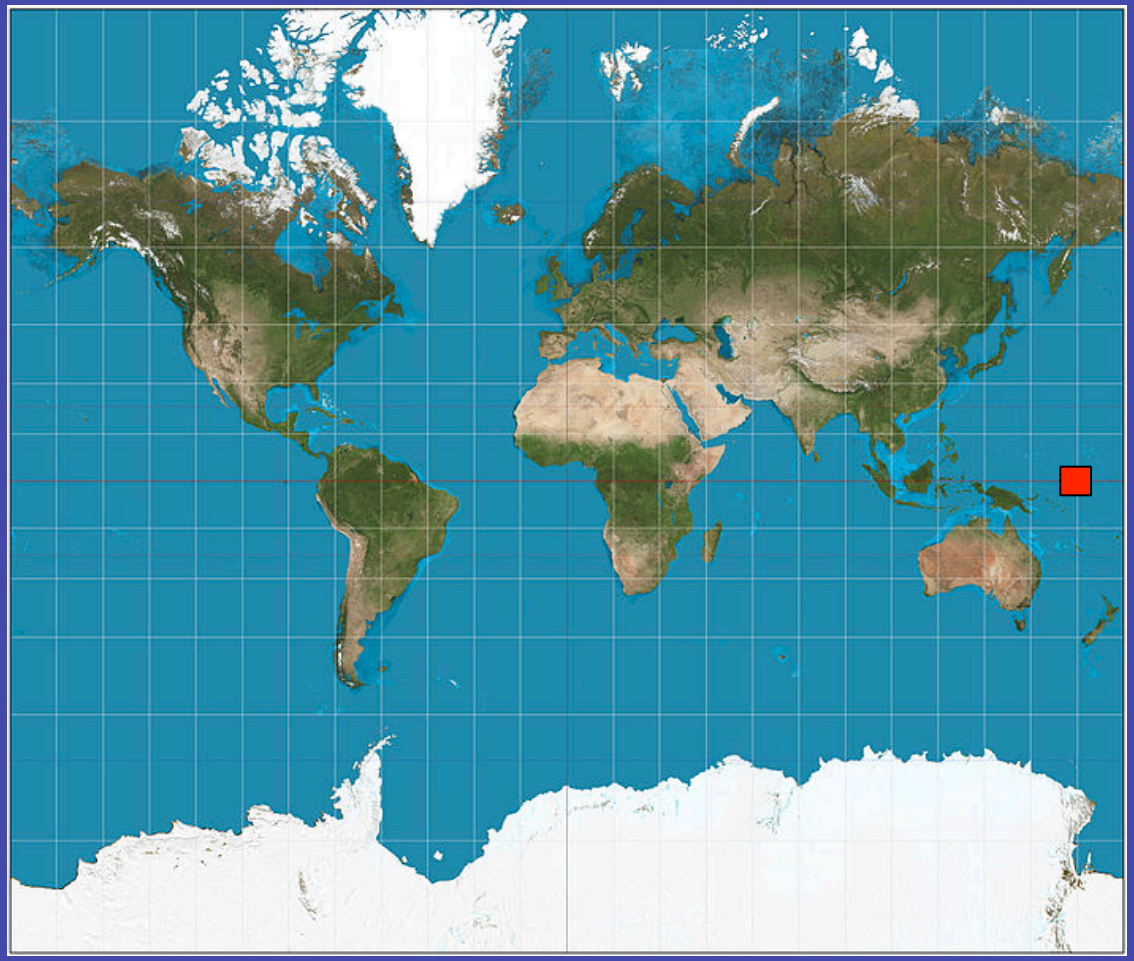
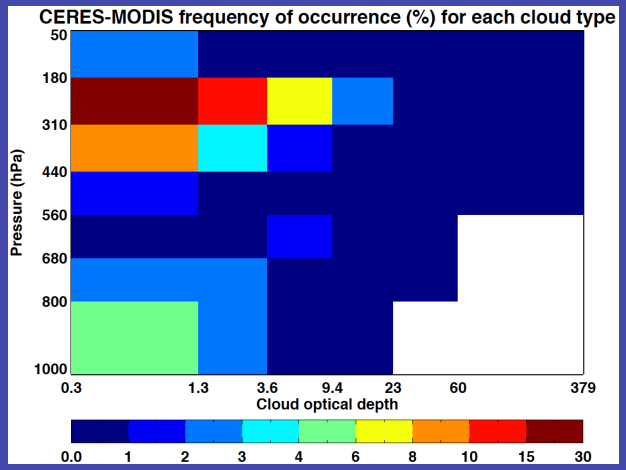


Image from Strebe, https://commons.wikimedia.org/wiki/File:Mercator_projection_SW.jpg

# Cloud fraction (%) for CERES, HadGEM2-A over Equatorial Pacific (Jan 2008)

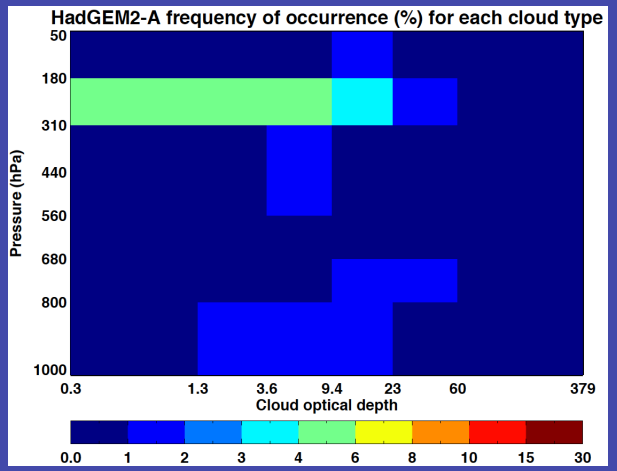
CERES




$p_c$

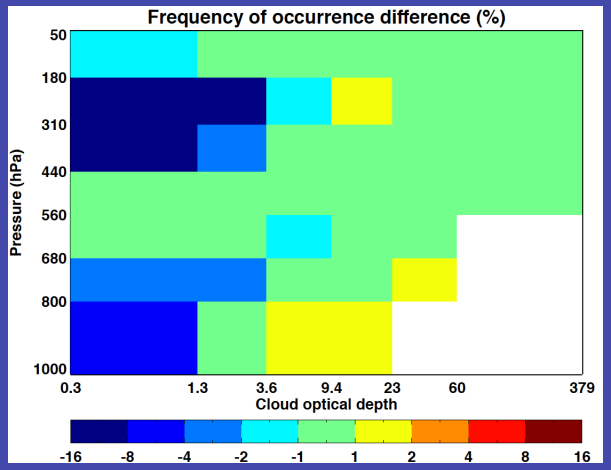
$\tau$

HadGEM2-A




$p_c$

$\tau$




$p_c$

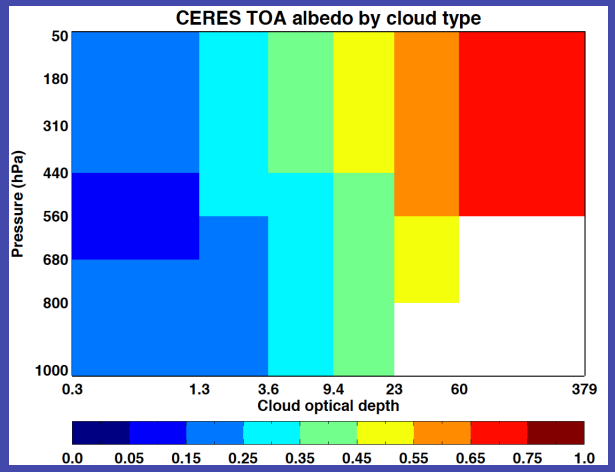
$\tau$

HadGEM2-A – CERES. Far too few clouds overall, especially for high, thin clouds.

Grid-mean total cloud fraction:
CERES: 0.798
HadGEM2-A: 0.397

# TOA SW albedo by cloud type for CERES, HadGEM2-A for Equatorial Pacific (Jan 2008)

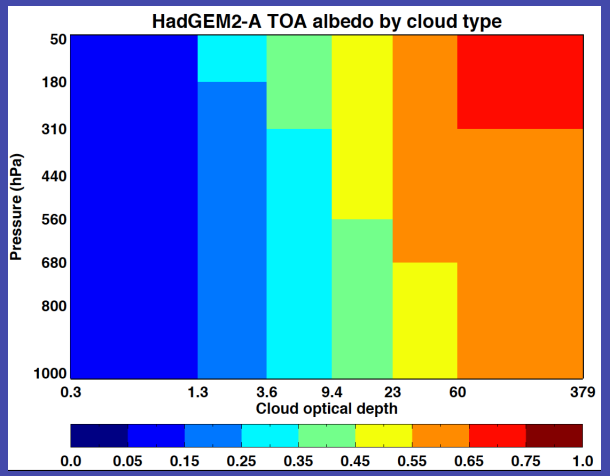
CERES




$p_c$

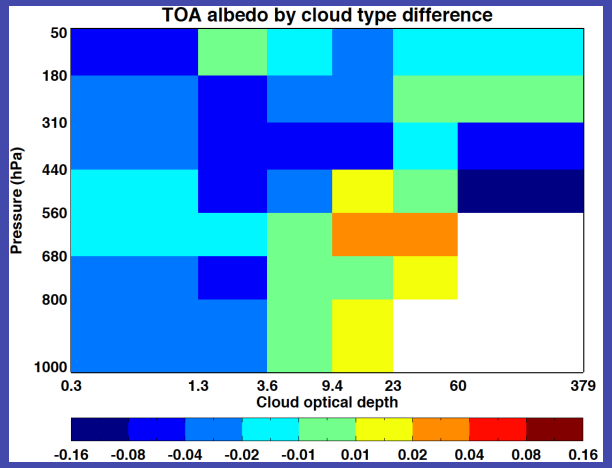
$\tau$

HadGEM2-A




$p_c$

$\tau$




$p_c$

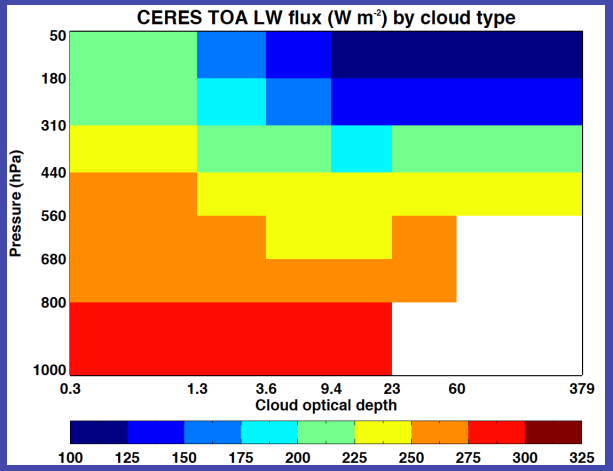
$\tau$

HadGEM2-A – CERES. Albedos a bit low for most cloud types, but high for medium/high optical depths at lower altitudes.

Grid-mean all-sky SW albedo:
CERES: 0.220
HadGEM2-A: 0.186

# TOA LW flux by cloud type (W $m^{-2}$) for CERES, HadGEM2-A over Equatorial Pacific (Jan 2008)

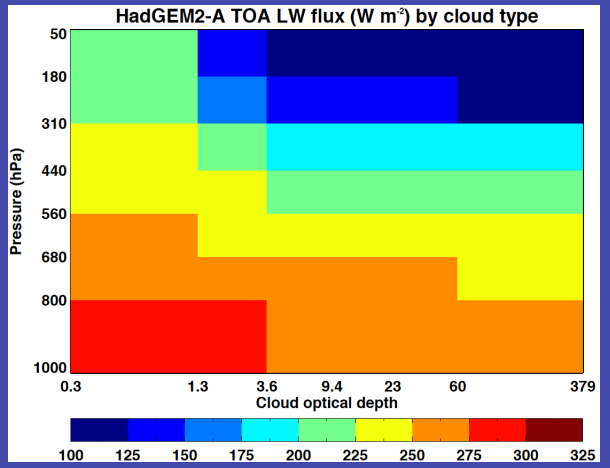
CERES




$p_c$

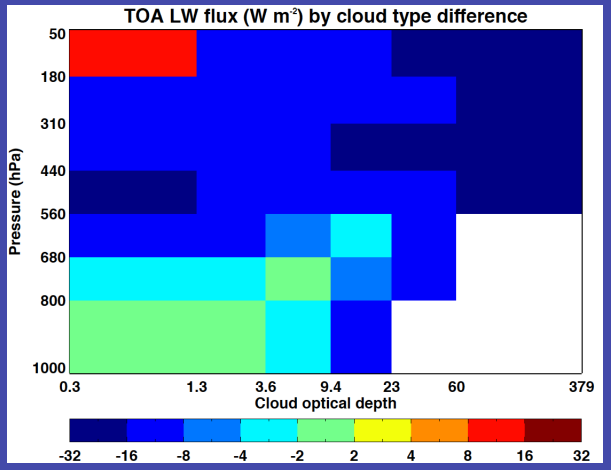
$\tau$

HadGEM2-A




$p_c$

$\tau$




$p_c$

$\tau$

HadGEM2-A – CERES. OLRs are low for almost all cloud types, except for highest, thinnest clouds.

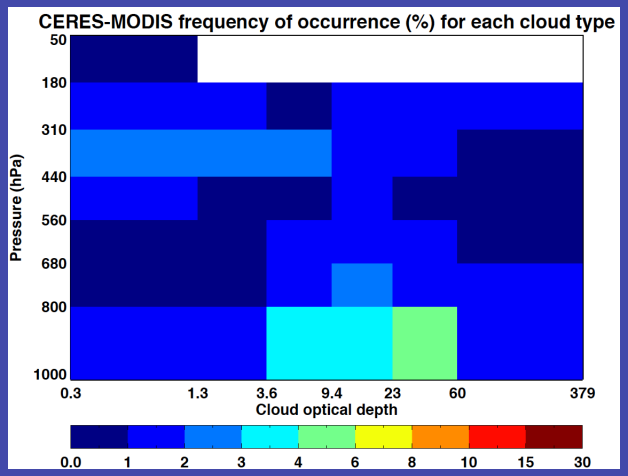
Grid-mean all-sky OLR:
CERES: 227.7 W $m^{-2}$
HadGEM2-A: 260.2 W $m^{-2}$

# Southern Great Plains results

Image from Strebe, https://commons.wikimedia.org/wiki/File:Mercator_projection_SW.jpg

# Cloud fraction (%) for CERES, HadGEM2-A over Southern Great Plains (Jan 2008)

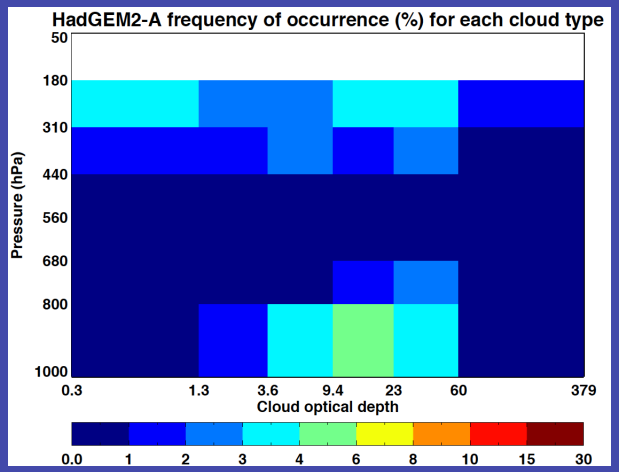
CERES




$p_c$

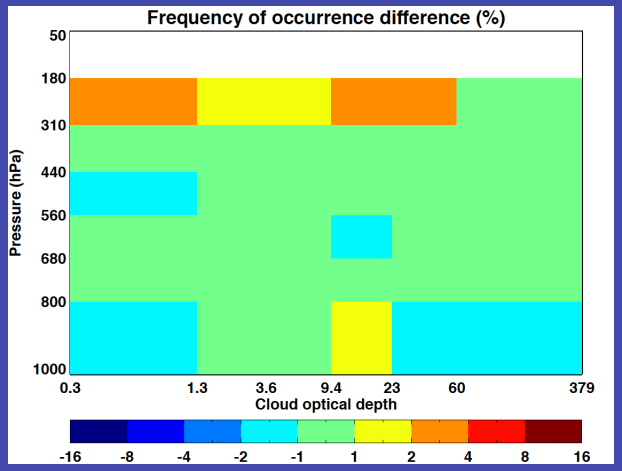
$\tau$

HadGEM2-A




$p_c$

$\tau$




$p_c$

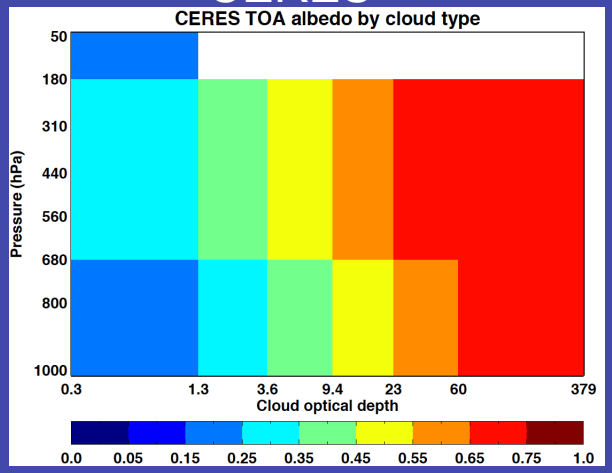
$\tau$

HadGEM2-A – CERES. Similar amounts of clouds for most types, but more high clouds than observed.

Grid-mean total cloud fraction:
CERES: 0.539
HadGEM2-A: 0.518

# TOA SW albedo by cloud type for CERES, HadGEM2-A for Southern Great Plains (Jan 2008)

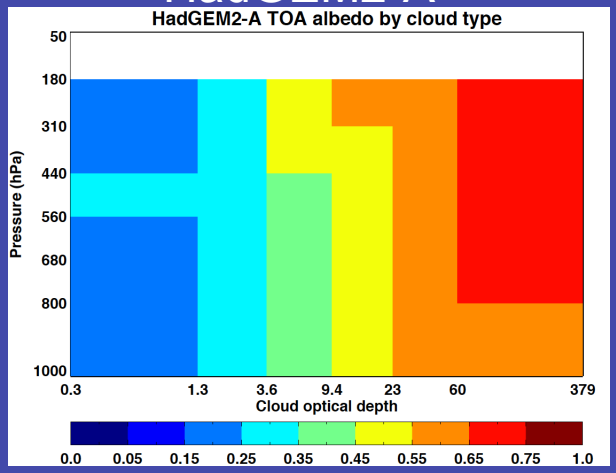
CERES




$p_c$

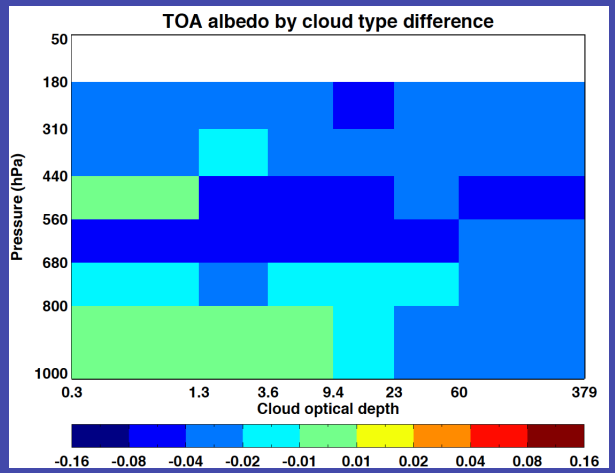
$\tau$

HadGEM2-A




$p_c$

$\tau$




$p_c$

$\tau$

HadGEM2-A – CERES.
Albedos low for most cloud types, especially at mid-levels.

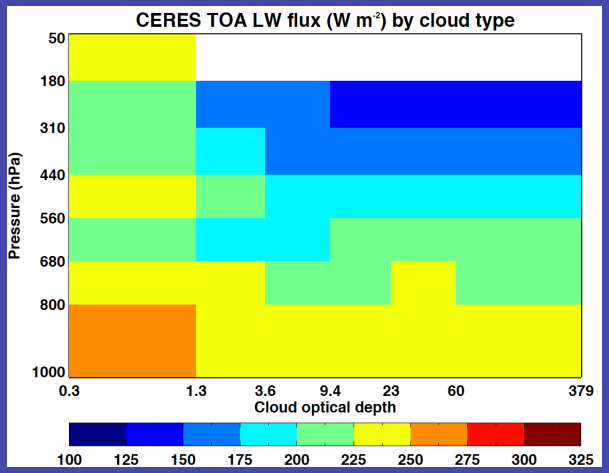
Grid-mean all-sky SW albedo:
CERES: 0.367
HadGEM2-A: 0.330

# TOA LW flux by cloud type (W $m^{-2}$) for CERES, HadGEM2-A over SGP (Jan 2008)

CERES

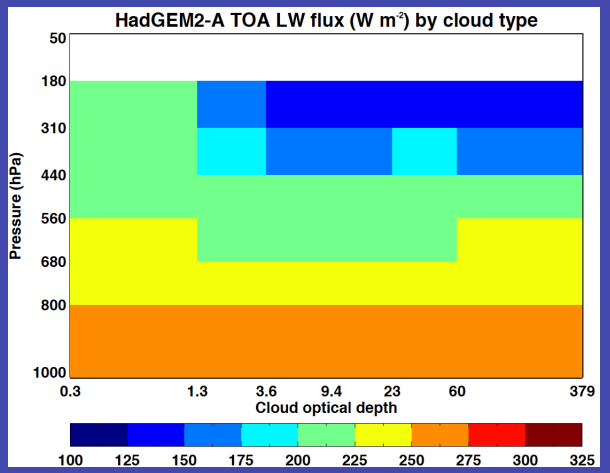
HadGEM2-A

$p_c$



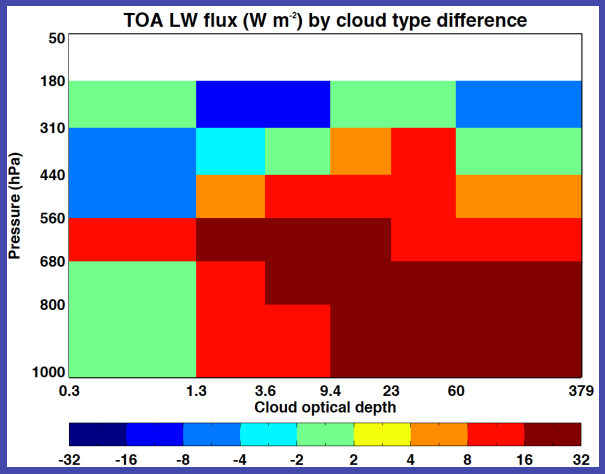

$\tau$

$p_c$




$\tau$

$p_c$




$\tau$

HadGEM2-A – CERES. OLRs are too high for most low, medium height clouds.

Grid-mean all-sky OLR:
CERES: 231.1 W $m^{-2}$
HadGEM2-A: 240.3 W $m^{-2}$

# Summary

- Identifying unique subcolumns reduces the number of RT calculations required by >95%.
- SW biases and RMS errors between the RT model and HadGEM2-A are relatively small, but there is a negative bias in OLRs.
- Over the SE Pacific, HadGEM2-A produces low clouds and has a realistic all-sky albedo, but the clouds tend to be too few and too thick.
- Over the Equatorial Pacific, HadGEM2-A produces far too few clouds, resulting in unrealistically high all-sky OLR, even though the OLR by cloud type is generally low.
- Over the Southern Great Plains, the cloud fraction is realistic, with clouds generally in the right place, but albedo is too low and OLR is too high, possibly indicating a problem with (too little) snow cover?